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Exploration of Abandoned Mine Shafts by means of Seismic Refraction, Electrical Resistivity Tomography, and Ground Penetrating Radar: Case study at Centralia, PA

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Introduction

- Electrical Resistivity is effective in finding subsurface voids due to their high resistance (Biswas et. al., 2005; Negri et al., 2015; Cardarelli et al., 2009).
- Ground Penetrating Radar has high resolution and accuracy to detect abandoned mine structures (Munk and Sheets, 1997; Biswas et. al., 2005).
- Seismic Refraction Tomography is traditionally used for Geological exploration (Cardarelli et al., 2009; Sheehan et al., 2005).
- A combination of geophysical techniques have been found to be most effective over individual techniques (Munk and Sheets, 1997; Cardarelli et al., 2009).
- This study combines ERT, SRT & GPR to identify mine shafts

Methodology

- Centralia, PA was selected as the main sample site for this experiment, due to the plethora of subsurface structure under the town (**Figure 1 & 2**)
- Located on the Locust Mountain Anticline in the Llewellyn Formation
- The Buck Mountain Coal Vein (bottom and middle splits) was mined at the sample site, with beds dipping at 12 degrees towards the south
- Room and pillar was the primary technique of mining at the sample site. **Figure 2** is an ArcGIS representation of this technique

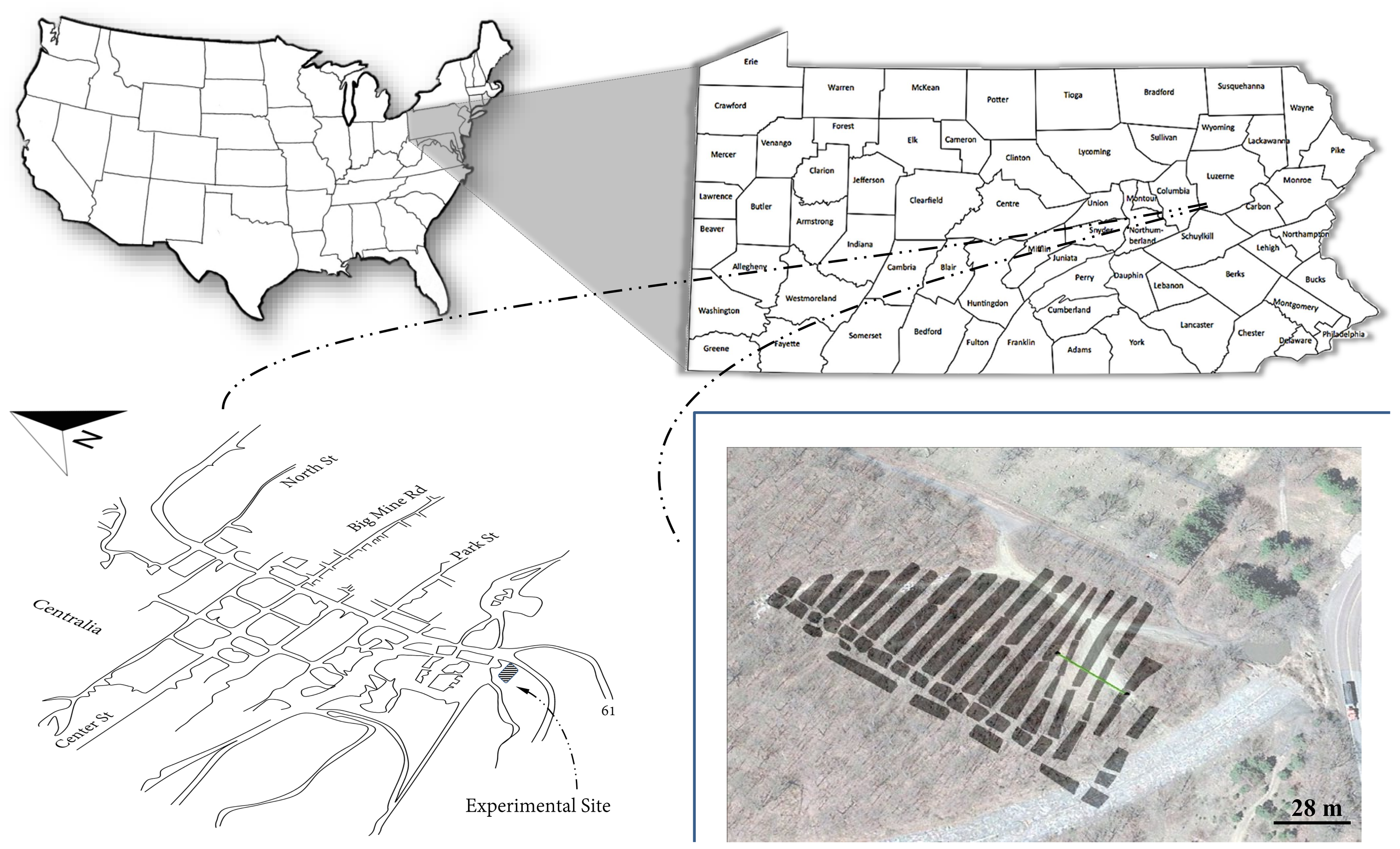

Figure 1: Sample site at Centralia

Figure 2: GIS image of mines at the sample site

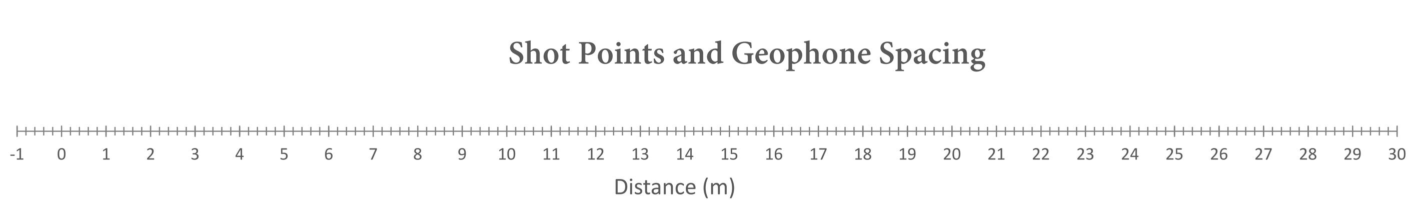

Figure 3: SR geophone spacing

- **Figure 3** represent the 24 geophones Seismic Refraction array deployed in this project. The first and the last two geophones had 2 m spacing
- One ERT survey was performed with 56 electrodes with 0.5 m spacing; using both Wenner and dipole-dipole configurations.
- A 100 MHz GPR survey was performed over the same transect for the ERT and Seismic refraction line.
- Two model surveys were also conducted over a known culvert with SR both using 24 geophones. The first survey performed 1 m spacing. And the second 0.5 m spacing. Both surveys had 7 shots.

Centralia Results

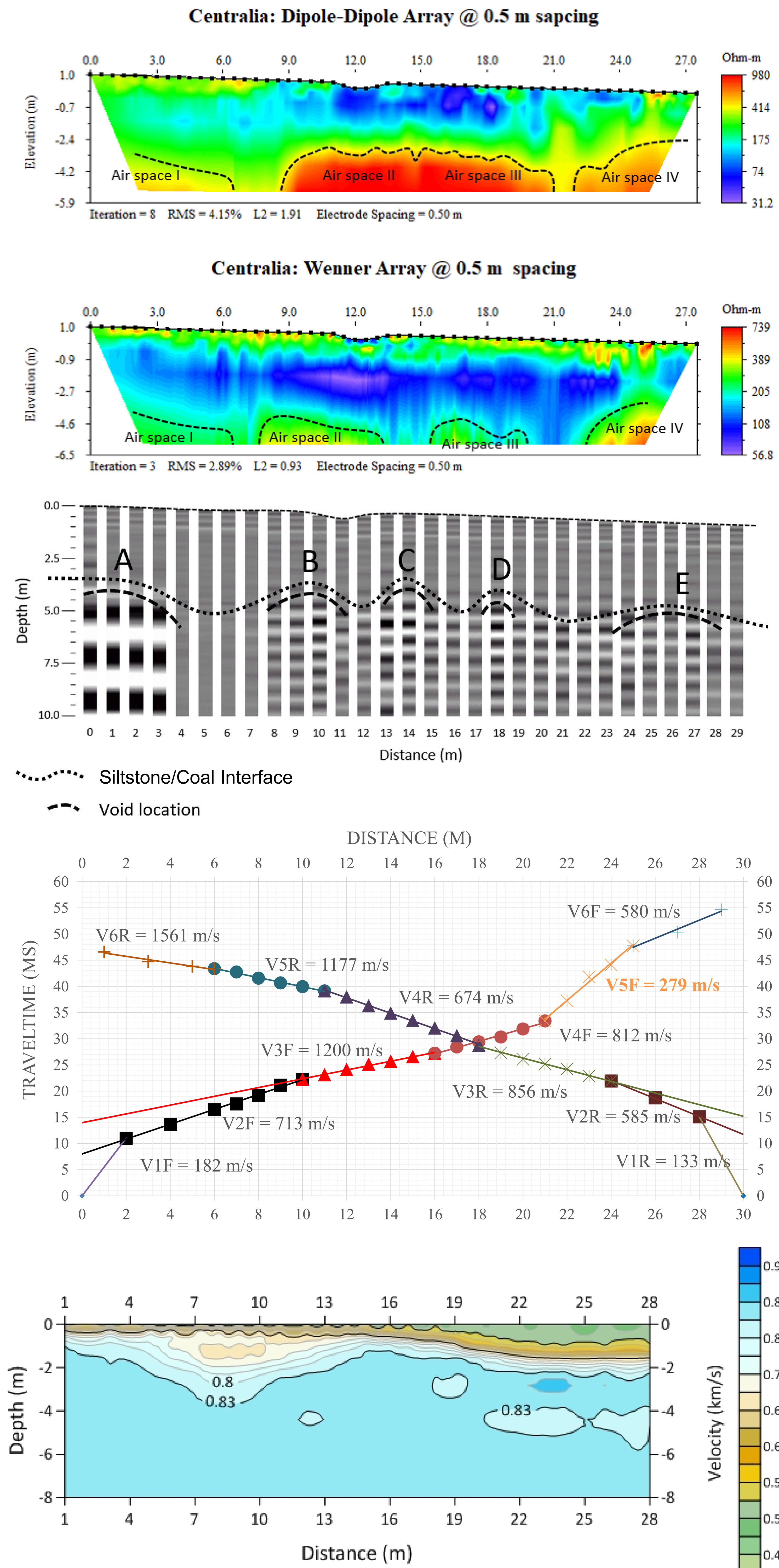

Figure 4: Comparative analysis of the geophysical methods

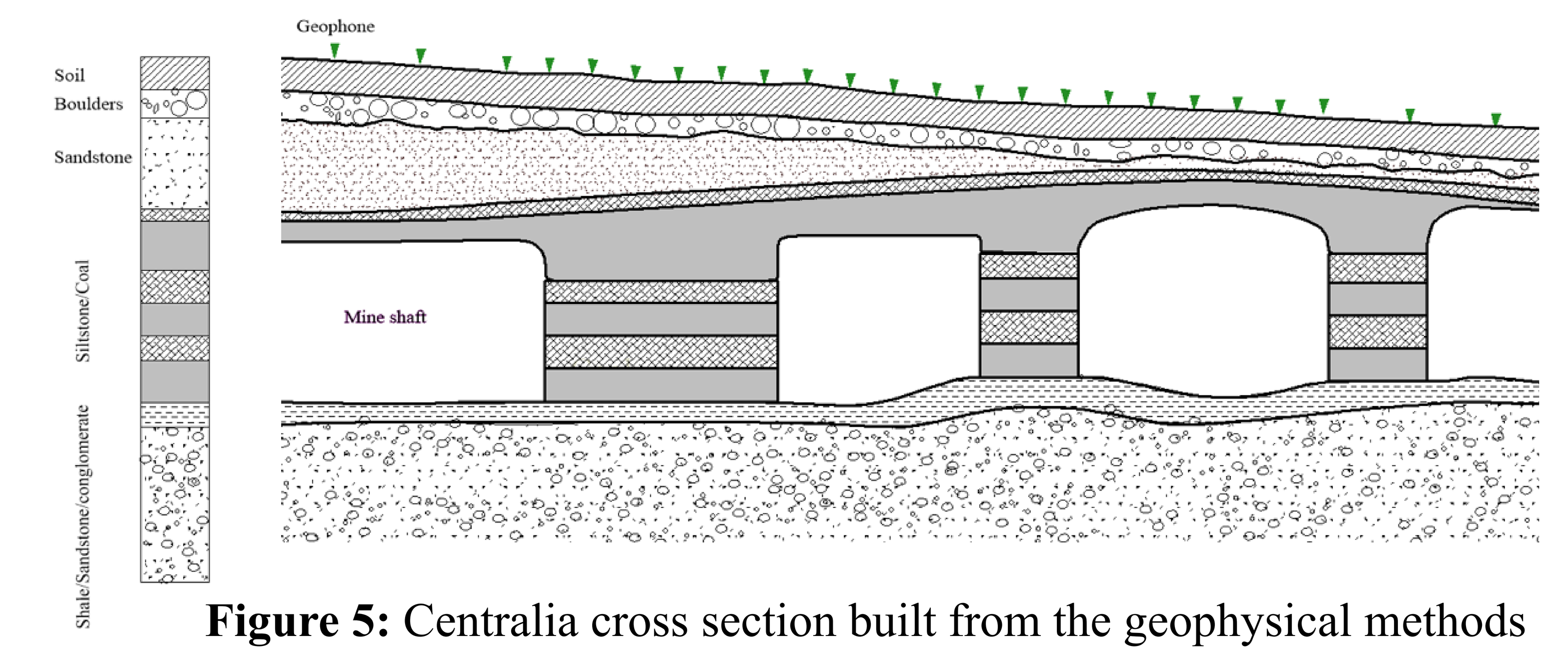

Figure 5: Centralia cross section built from the geophysical methods

Model Results

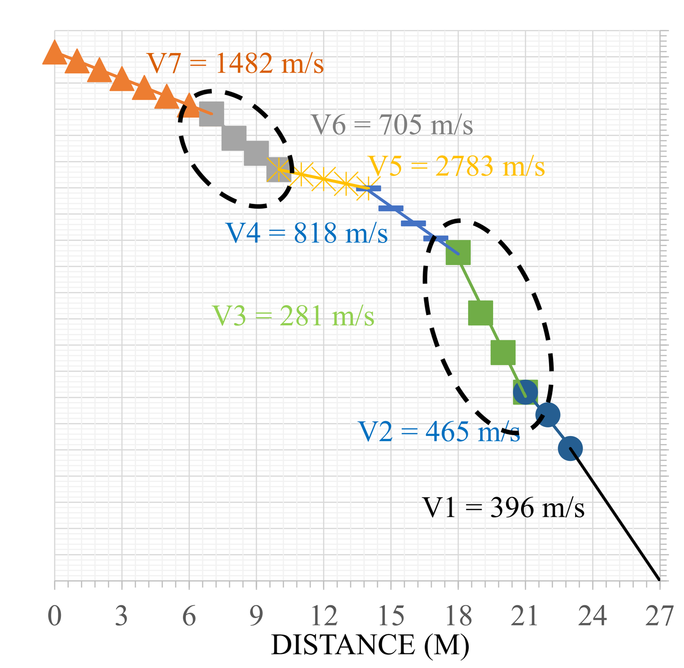

Figure 6: Comparison of Time-Distance Graph from the 1 m model. Circles show delays in anticipated arrival times (like that in VF5).

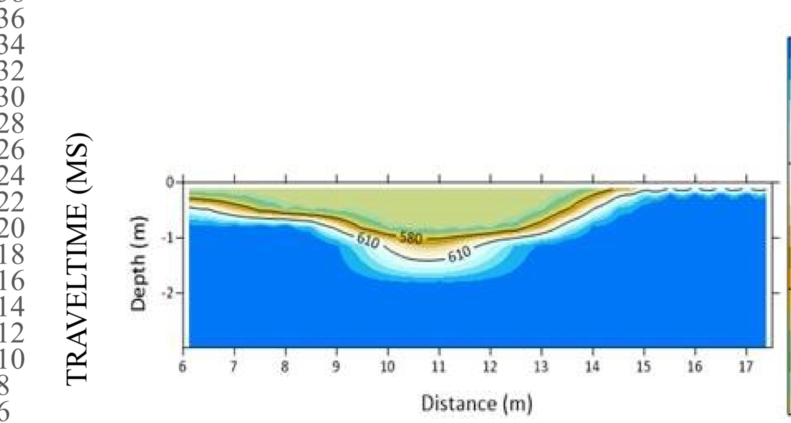

Figure 7: Model 0.5 m SRT survey with "depression" in the center.

Discussion

- Significant noise on the GPR 2D transect made identification of the shafts hard. Instead, a point by point survey was used. The 5 shafts detected by the survey are shown by the dotted lines in **Figure 4.**
- ERT contained areas of high resistivity shown in both the Wenner and Dipole-Dipole, indicative of subsurface void spaces (**Figure 4**).
- The signature of void spaces for SRT are depressions in the 2D transect between 800 – 1000 m/s (Maraio et al., 2014; Riddle et al., 2010). This was replicated in the model (**Figure 7**).
- The signature of void spaces in time-distance plots is an unanticipated delay in arrival times (Ballard, 1982). This was replicated in the model several times (**Figure 6**).
- SR and ERT were the preferred methods of mine structure detection, as they revealed the most information about the detection of the 4 voids and their respective placement.

References

- Ballard, R. F. Jr. 1982. Tunnel Detection. United States Army Corps of Engineers: Geotechnical Laboratory, U.S. Army Engineer Waterways Experiment Station. Technical Report GI-82-9.
- Biswas, U. K., et al. 2005. Detection of sub-surface voids by surface geophysical methods in Baktarnagar area of Raniganj coal field, West Bengal. Special Publication Series, 81. pp. 198-210.
- Cardarelli, E. et al. 2010. Electrical Resistivity and Seismic Refraction Tomography to Detect Buried Cavities. Geophysical Prospecting, 00. pp. 1-11.
- Maraio, S., et al. 2014. Application of Seismic Refraction Tomography to detect Anthropogenic Buried Cavities in Province of Naples (Campanian Plain, Italy). GNGTS 2014. pp. 90 – 94.
- Munk, J., and Sheets, R.A. 1997. Detection of underground voids in Ohio by use of geophysical methods. U.S. Geological Survey Water-Resources Investigations Report, 97–4221.
- Negri, S., et al. 2015. Integrated Analysis of Geological and Geophysical Data for the Detection of Underground Man-Made Caves in an Area in Southern Italy. Journal of Cave and Karst Studies, 77. No. 1, pp. 52-62.
- Riddle, G. I., et al. 2010. ERT and Seismic Tomography in Identifying Subsurface Cavities. GeoCanada 2010. pp. 1-4.
- Sheehan, J. R., et al. 2005. Application of seismic refraction tomography to karst cavities. USGS Karst Interest Group proceedings. pp. 29-38.